Report 5412

31 August 1961

FINAL REPORT

EX-38 500 LB. CHEMICAL BOMB DEVELOPMENT

Prepared by ____________
F. F. Taranto

Approved by ____________
S. Klurfeld

EDO CORPORATION
COLLEGE POINT, NEW YORK, U.S.A

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF REFERENCES

1. Chemical Bomb EX38 Phase I Summary Report, Vols. I and II, Edo Report No. 5150, Confidential, June 1960

2. Structural Analysis of the EX38 - 500 lb. Chemical Bomb, Edo Report No. 5490.

3. Aerodynamic Characteristics of the EX-38 Chemical Bomb, Gauzza, H. J., NAVWEPS Report 7255, Confidential, 16 August 1960.

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

1.0 SUMMARY OF PROJECT

1.1 Purpose

This report is the final report of Contract No. DA18-108-405-CML-438 between the Chemical Warfare Laboratories of the U.S. Army Chemical Center and the Edo Corporation. The contract called for the design and fabrication of the EX-38 500 lb. chemical agent bomb. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized herein.

The primary purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient, 500 lb. massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft systems for accurate delivery were the most important objectives. A payload in excess of the current Navy operational chemical bombs was required; that is, on the order of 60% of gross weight. Furthermore, the bomb stability, and hence bombing accuracy, should be superior to that achieved by a standard 500 lb. Navy Low Drag shape. The development of a dependable leak proof bomb suitable to low cost large scale production was also an important purpose of the contract.

1.2 Results

The bomb designed and developed under this contract meets all the major design objectives. Analyses and

tests on the prototypes confirm the successful development of the EX-38 chemical bomb.

1.2.1 Bomb Aerodynamics

The bomb shape chosen possesses the desired aerodynamic characteristics together with a maximum useful payload volume. The free flight drag characteristics are far superior to the standard Navy General Purpose bombs and approaches the efficiency of the Navy Low Drag shaped bombs. With EX-38 bombs mounted externally on the Navy carrier planes (FJ-4B, A4D, and A2F), no difference in aircraft speeds or characteristics should be discernible when compared to flights carrying a similar weight of bombs using the Low Drag shaped. Moreover, the aircraft performance with EX-38 bombs should be noticeably superior to that with standard G.P. bombs of equivalent weight.

Good bomb stability in free flight is truly a more significant consideration than a minute change in aircraft performance since it provides the accurate and predictable trajectory necessary for an efficient bombing system. In this respect the EX-38 bomb will permit greater bombing accuracy than any currently existing CW bomb. This improved stability has been achieved by the forward ballasted center of gravity and the large span tail. The tail span is 1.6 times the maximum body diameter compared to the near standard value of 1.4 times diameter of existing bombs. Use of the larger

span will in no way restrict extenral carriage on Navy aircraft. Internal carriage in the A3D will be limited to three bombs.

Bomb stability is further enhanced by the development of the CWL designed baffle to restrict the c.g. movement of the liquid fill. Because the bomb is only 90% filled to allow for fluid expansion, a 4.5 inch c.g. shift could occur during pitching motions if no void control were provided. However, with the baffle the c.g. travel is restricted to only 1.3 inches. The effectivenss of this baffle depends on the principle of trapping the air void or "bubble" in the rear of the tank, rather than on any damping principle.

1.2.2 Bomb Payload

The prime goal of an efficient payload capability has been achieved. The 311 lbs. payload (with a 10% void) is 61% of the total gross weight of 515 lbs. This represents a considerable improvement over existing munitions. For example, the MC-1 bomb, which is typical of existing CW munitions, carries only 220 lbs. of agent out of a total gross weight of 709 lbs. for an efficiency of 31%. The significant increase in EX-38 payload was achieved by expanding the useful volume (hence the new shape already mentioned) and by the utilization of an extremely efficient light weight structure. In addition to increasing payload, the light weight structure should facilitate handling during the production and filling of the bombs. The

empty bomb weight is only 164 lbs. compared to 463 lbs. for the MC-1 bomb.

1.2.3 Bomb Structure

The prototype bombs passed all structural tests in a completely satisfactory manner. These tests were designed to simulate forward, aft and side ultimate inertia loads of specification MIL-A-8591B, bomb rack ejector load, tail airloads, and rough handling loads. Structural integrity for loadings not simulated in test is substantiated by adequate stress analysis margins of safety. After completion of all these tests the first bomb was subjected to a rough handling drop test. This test provides proof that a welded, light weight aluminum tank can be a safe container for CW agents. The bomb was dropped ten feet onto a concrete floor and showed zero leakage using a sensitive helium leak detector.

1.2.4 Miscellaneous

Several other features of the bomb design represent successful results of this contract. First, the bomb can accept the standard Navy fuzing systems including both the electrical and mechanical types. Second, the tail cones are interchangeable and can be easily installed in less than one minute by one man using only a screw driver.

Finally the design is conducive to low cost large scale production. The "Hydro-Spin" process (a metal working rather than a metal cutting process) used in making the tank shell are particularly adapted for large production runs. Likewise, the molded plastic tail fins are suitable

for low cost mass production. The estimated unit cost of $1300 for a run of 1000 units is indicative of the economy of this design in production size runs. This cost is based on the existing design and tools. Further reduction in cost is possible by an additional modest investment in tools and production engineering.

1.3 Timetable of Contract Work

The progress of work under this contract is summarized in the following timetable:

August 1959 -	Actual Phase I design study begun.
Jan. 19, 1960-	Phase I design study report completed and submitted to CWL for approval (Except Appendix F - Dynamic Stability Calculations which was submitted on February 9, 1960).
Jan. 29, 1960-	CWL review of Phase I report completed. Edo requested to effect certain detail design changes and to estimate costs of production hydrospinning tools. Authorization given to initiate procurement of strongback extrusion.
Feb. 24, 1960 -	Detail changes to Phase I design and cost estimates of Phase II completed and delivered to CWL. Phase II detail manufacturing drawings begun, except items awaiting confirming decisions; Hydrospinnings, tail

fins, and tail attachment.

March 9, 1960-	Complete authorization received to begin Phase II including additional costs of hydrospin tooling and a bayonet type tail attachment.
May 5, 1960-	Wind tunnel tests at Naval Ordnance Labs. of EX-38 bomb model completed and requirements for tail fins delivered to Edo.
May 1960 -	By the end of this month all detail parts designed and released for purchase except final assembly and tail cone parts.
July 1960 -	All parts were on order by this date.
August 29, 1960-	CWL Project Officer inspected and accepted prototype bombs for shipment to CWL.
Sept. 14, 1960-	Two prototype bombs of Phase II shipped to CWL.
October 20, 1960-	Evaluation of prototypes by CWL completed and Edo authorized to begin Phase III.
November 1960 -	All parts for ten Phase III bombs released for purchase.
Feb. 3, 1961 -	Four bombs (Nos. 3 through 6) shipped to CWL.

March 20, 1961 - Last six bombs (Nos. 7 through 12) shipped to CWL.

1.4 Recommendations

As a result of the accomplishments of this contract, the following recommendations are made:

1. Continue the operational development program planned for Navy standardization of the EX-38 bomb.

2. Examine the adaptation of the EX-38 bomb to other Naval requirements developed since the initiation of this contract.

3. On subsequent bombs:

   a. Redesign tail fins to utilize the lower cost molded glass reinforced Phenolic.

   b. Design steel inserts at the suspension lug holes to utilize standard Navy suspension lugs.

4. Provide sufficient tool and production engineering for subsequent large scale production of the EX-38 bomb.

2.0 PHASE I - DESIGN STUDY

2.1 General

The object of the Phase I Design Study was to achieve a bomb design which would provide a maximum payload, be compatible with transonic external carriage on and delivery from existing Navy aircraft, be suitable for low cost high production manufacturing techniques, have a high degree of leak-tightness under handling requirements, and be compatible with both the Navy electrical and mechanical fusing. These five general objectives were carefully specified in the contract documents and in subsequent discussions with personnel of CWL. Thus, any review and evaluation of this program must be made with these initial objectives in mind.

2.2 Salient Features of the Design

Figures 2.1 through 2.9 give an accurate description of the bomb design evolved during this Phase I study. Briefly the bomb is composed of a long tank with a central well or tube running full length for the explosive burster. A nose fairing and ballast assembly is tack welded to the front end of the tank and a finned tail assembly is attached to the rear end of the tank by a quick disconnect bayonet attachment.

The physical characteristics of the bomb are listed in Table 2.1. The net payload of 61% should be noted. This high ratio of payload to gross weight satisfies one of the primary goals of the contract.

The construction of the tank portion of the bomb (See Figures 2.3 and 2.4) consists of two similar tank ends, a central cylindrical section and the burster tube. The cylindrical section contains two circular frames, an extruded strongback reinforcement, a slosh baffle and the arming wire conduit. These units are welded together by means of two circumferential welds on the O.D., and 2 circumferential welds to the burster tube. Additional pressure tight welds are made at the bomb lugs, at the two bosses in the aft end and at both ends of the internal arming wire conduit. Total length of pressure tight welds is 154 inches.

Since the tank end domes and center cylinder are formed by a hydrospinning process, no longitudinal weld is necessary. The domes were spun from a 5/16 in. performed flat plate and the cylinder was spun out from a ring forged cylinder 17 in. long machined to 13.8 in. I.D. with .324 in. wall. Figure 2.7 shows these spinnings.

By using the hydrospinning process the design attempted to minimize the number and length of welds in the basic chemical agent container. A number of alternate designs were reviewed. One such alternate utilized a much longer hydrospinning combining the cylindrical portion and one end dome all in one piece. In this case, one O.D. circumferential weld seam would be eliminated. Another case considered later, (during Phase II a vendor proposed and made some serious studies of this scheme) was similar

except that the preforms for the spinnings would be machined forgings which would have the rear bosses integral with the part. Thus, the welding of the bosses would be eliminated. Both of these alternates would have entailed greater tooling costs and would depend on a spinning which would closely approach the limits of the hydrospinning process itself. The original design was settled upon rather than these more sophisticated alternates, because it was the least costly, more readily feasible and more in keeping with the intent of the contract. In fact, the design finally selected involved tooling costs in excess of the original contract estimated costs.

Other important design features pertain to the handling characteristics of the bomb. Because of its bayonet attachment, the tail is easily installed by one man using a screw driver. With a simple push and twist the bayonet fitting is engaged. Then with a screw driver the locking screw is tightened. Figure 2.4 shows one half of the bayonet joint in clear detail.

Provisions has also been made in the detail design of the bomb to permit the alternate use of the standard Navy mechanical fuse system as well as the electrical type. Figure 4.1 shows this mechanical system installed in the bomb. This adaptation has been made possible by a special threaded fitting on the rear most end of the tail cone and by the appropriate fuse holders and burster tube end fittings.

A further handling advantage of the EX-38 bomb should be realized simply by virtue of its light dry weight. Its dry weight (exclusive of fusing) is only 164 lbs., as compared to the 463 lbs. dry weight of the MC-1 bomb. Total weight of the MC-1 is 709 lbs. with 220 lbs. of agent.

2.3 Summary of Design Study

The design report (Edo Report No. 5150) which covered the study phase of the work gives in a very complete fashion all of the analyses, test results and reasonings that went to make up Phase I. As such, Report No. 5150 may be considered a part of this report. It is a complete record except that it does not include the modifications to the design that were required by the CWL. These modifications concerned the compatibility of the bomb fittings with existing fuse systems and changes required by the wind tunnel tests of the design.

Here it remains only to outline the subjects studied, and present the wind tunnel test results.

2.3.1 Aerodynamic Studies

A considerable effort was expended on several studies concerning the aerodynamics of the bomb while being carried by the aircraft, during ejection and during free fall. This effort was considered necessary to produce a bomb capable of being reliably delivered on target by high speed, high altitude Navy planes.

The first of these studies produced the shape of the bomb body and tail. The bomb body shape is a unique result of a compromise in which the requirements of low transonic drag, high payload, and producibility are all considered. The existing Navy Low Drag bomb shape did not provide the best compromise despite a slight advanatage in drag characteristics. Thus, a new shape was derived. This shape has long enough nose and tail tapers to ensure low transonic drag, and yet permit a long cylindrical liquid tank with identical end domes.

The studies made to optimize the tail fin sizes were based on using a span limited to 1.4 times the maximum bomb diameter. The aerodynamic coefficients required for this study were determined analytically using linear theory. The method and results of this study were primarily responsible for encouraging CWL to conduct the experimental optimization of the tail in the Naval Ordnance Lab's wind tunnel.

The other important aerodynamic studies were of the dynamic stability of the bomb in free flight and the separation from the aircraft. The free flight stability was checked at several points along the approximate trajectory by assuming only three degrees of freedom; roll, pitch and yaw. The trajectories were computed using a two degree of freedom analysis. Then from the speed, altitude and time relationships so obtained, rolling speed versus time relationships were

computed for various fin cants. (One degree of freedom is here assumed, i.e. freedom to roll).

The supposition of these rolling speed, altitude and forward speed versus time relationships constituted the approximate trajectory for which dynamic stability checks were made. Thus, at some instant of time the corresponding Mach. No., altitude and roll velocity are assumed to remain constant while the dynamic stability including yaw, pitch and roll coupling is checked.

In all, five complete trajectories were computed including roll histories. Ten trajectories without roll histories were computed. Dynamic amplification of pitching angles were computed for some fourteen or more points on each of the five trajectories and repeated for 1/2°, 1° and 2° fin cant.

This study indicated that the 2° fin cant was desirable. Hence the bomb design includes a permanent fin cant of 2° off the bomb centerline.

The study of the bomb separation from the aircraft was made assuming two degrees of freedom, pitch and downward translation. The results indicate that the EX-38 bomb as designed will eject and separate cleanly from the aircraft without striking the aircraft or pitching excessively.

2.3.2 Rough Handling Studies

The rough handling requirement of no leak after a ten foot drop was considered as the severest structural requirement for this bomb. Therefore, a simple test program was carried out to determine which of several structural materials and arrangements would be most efficient in absorbing energy without cracking or rupturing the tank. The tests did not attempt to duplicate the hydraulic pressures that may develop when the tank volume is reduced by deflections upon impact.

Seventeen samples of construction were tested. This series of tests provided valuable data needed for developing the final design. The design of the tank girth weld as well as the bulkhead installation were shown to be capable of withstanding considerable deformation without tearing or cracking the outer shell.

2.3.3 Stress Analysis

Design loads for the bomb were computed as specified by the requirements of MIL-A-8591. These requirements covered all loads imposed on the bomb while it is attached to the aircraft. For free flight of the bomb, loads were computed assuming a maximum pitch of 20 degrees at the maximum aircraft speed. A preliminary stress analysis was conducted using these loads.

The final stress analysis is presented separately, in Edo Report No. 5490.

2.4 CWL Wind Tunnel Test Results

After Edo submitted the Phase I Design Report, the U.S. Army Chemical Labs had a 1/8 scale model of the bomb tested in the wind tunnel facility of the Naval Ordnance Laboratories. Besides testing the recommended configuration, three larger sized tails were tested. These three configurations had larger spans; 1.6D, and varying chords; 1.10D, 1.40 D and 1.65 D.

The static coefficients for all models are shown reproduced in Figures 2.10a through 2.10b. All data are for Mach. 0.80. As a result of these tests the largest fin was specified for use on the bomb. This fin has a 1.60 D span and a 1.65 D chord. With this fin the bomb has the highest moment curve slope throughout the entire range of angles of attack and hence should have superior stability characteristics.

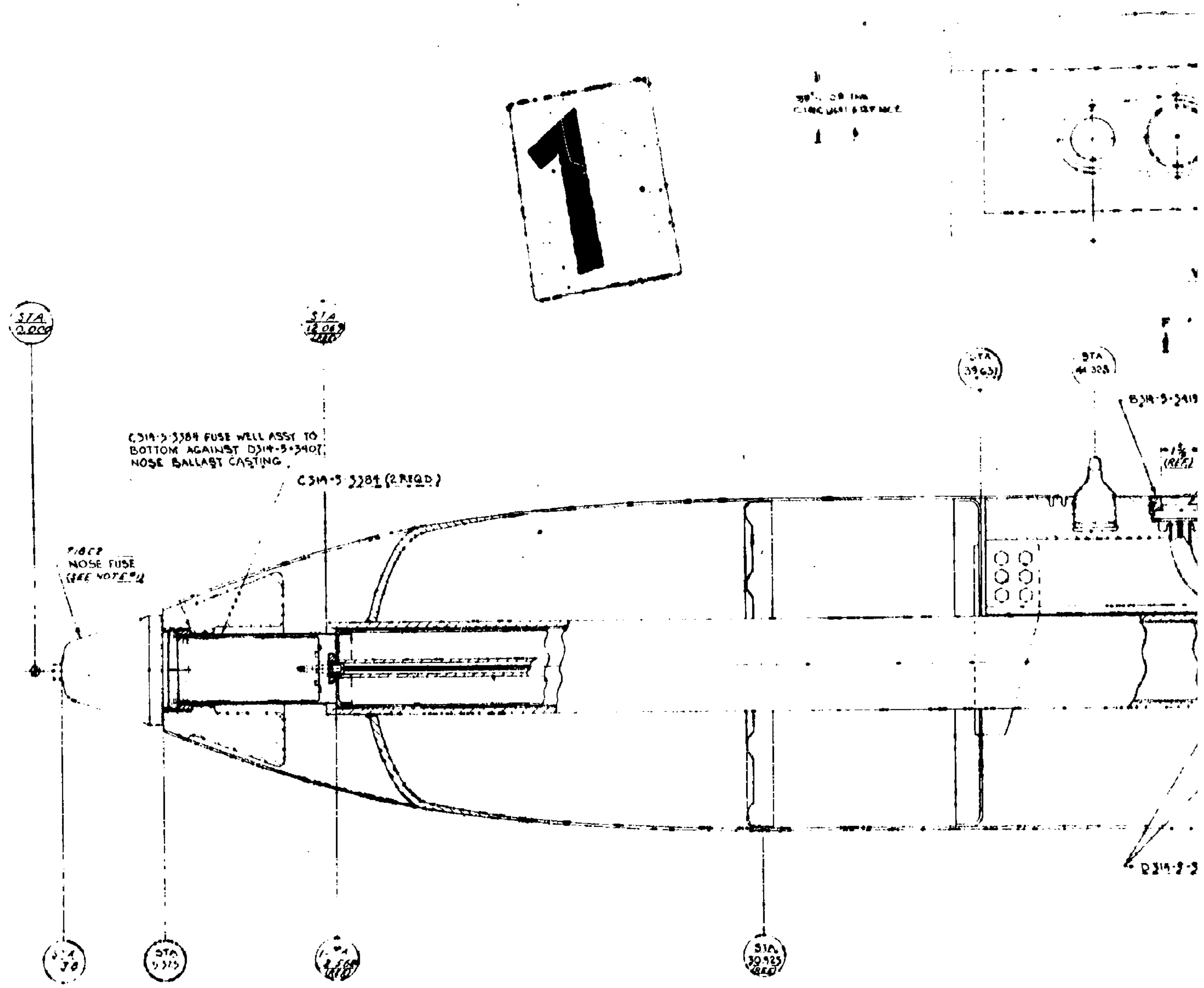
Reference 3 gives a complete report of these wind tunnel tests.

TABLE 2.1

EX 38 - CHEMICAL BOMB - PHYSICAL PROPERTIES*

Weights		
Forward Body Assembly		143 lbs.
Tail Assembly		21
Burster Charge Assemblies		32
Fuse (Electric System)		8
Agent (90% Full)		311
Total		515 lbs.
Payload to Gross Weight Ratio		61%
C.G. Position (90% FULL)	Sta	50.7
Overall Length - Less Fuze		116.3 in.
With Fuze		120.5 in.
Maximum Dia.		14 in.
Mass Moments of Inertia - Transverse		2607 $lb.ft^2$
Roll		42 $lb.ft^2$

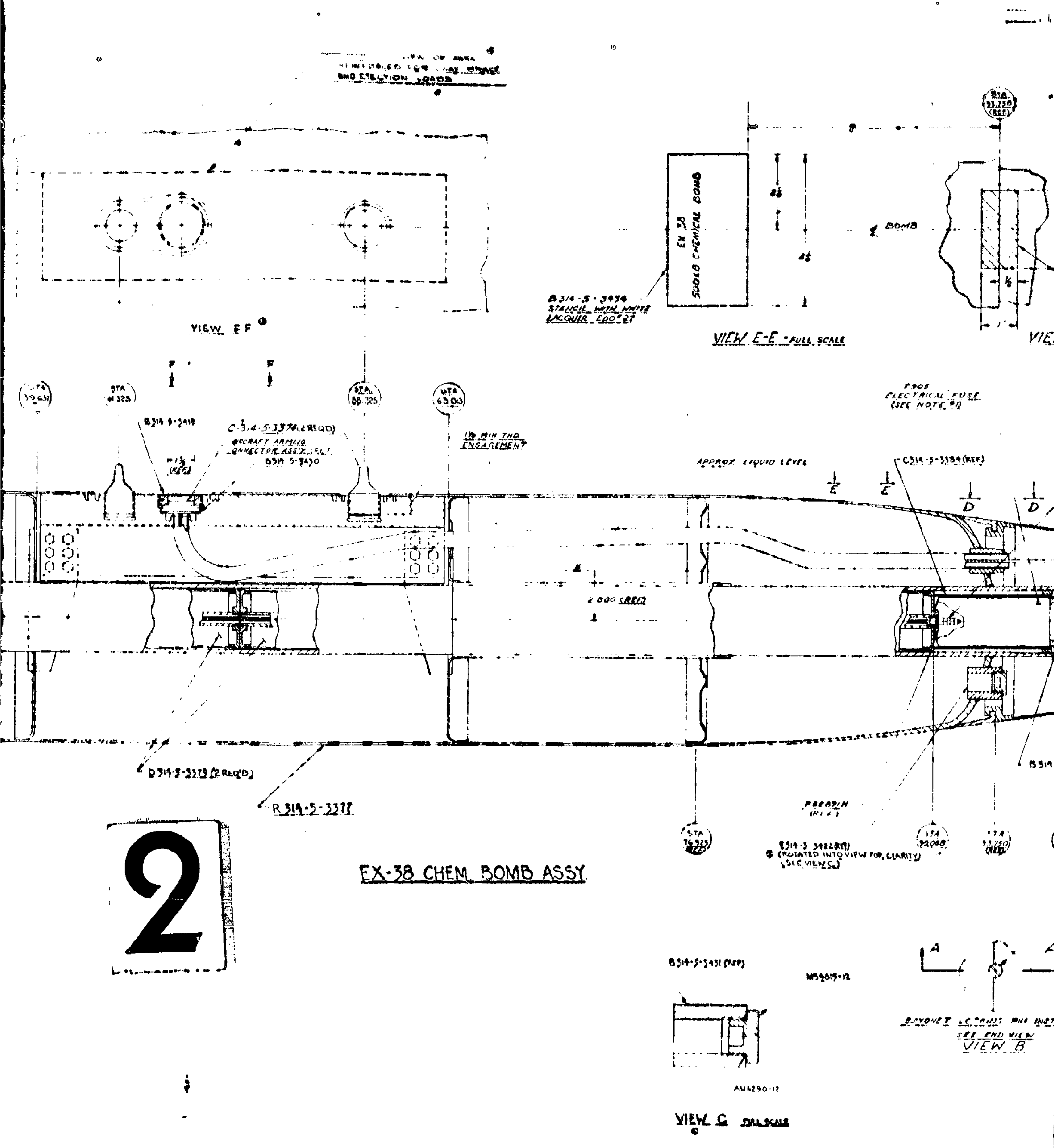
*Measured values



WEIGHTS

FWD BODY ASSY	143 LBS
TAIL ASSY	21 LBS
AGENT	310 LBS
FUZING	8 LBS
BURSTER	32 LBS
TOTAL	514 LBS

SECTION AT STATION [illegible]



EX-38 CHEM BOMB ASSY

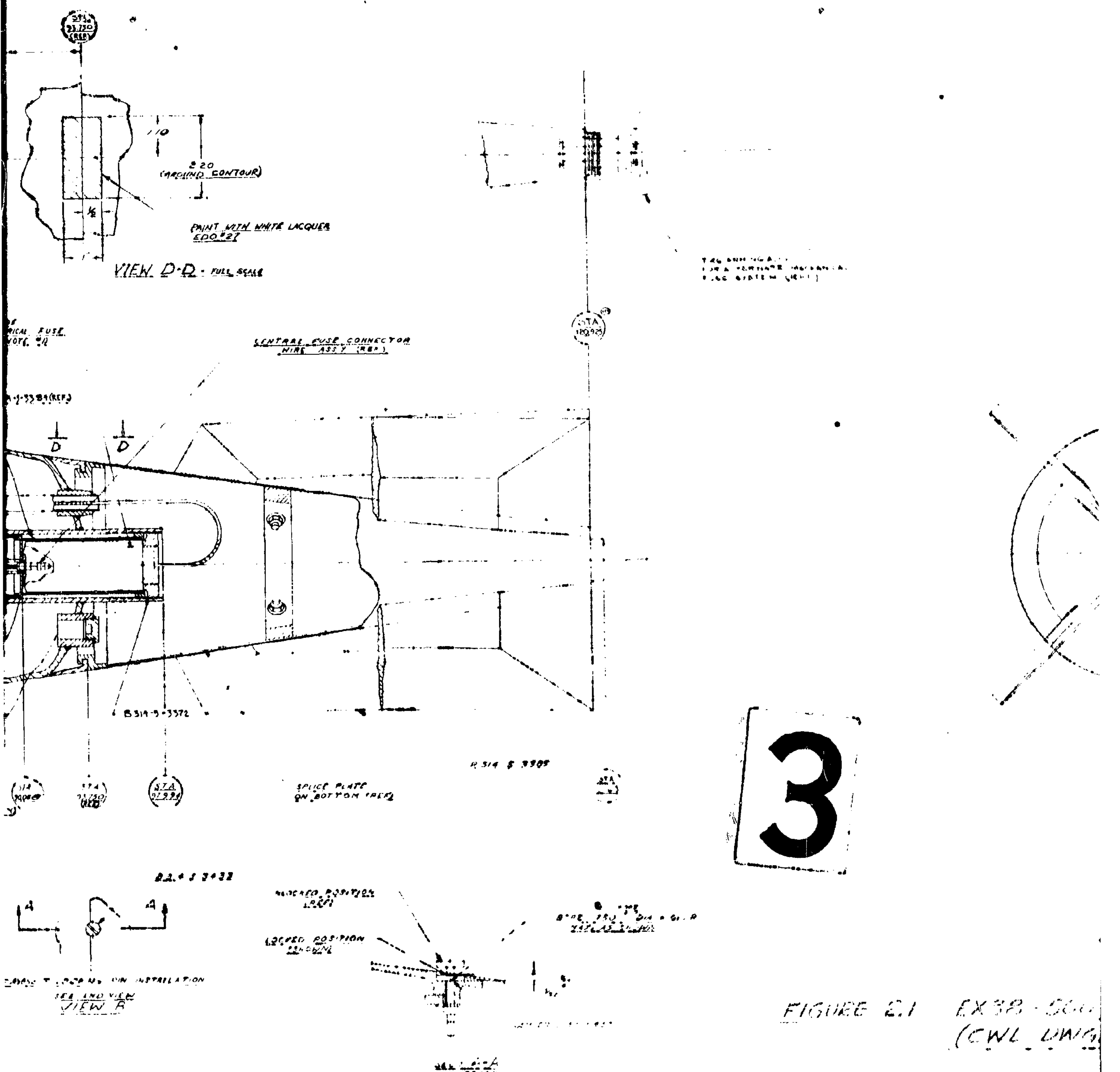


FIGURE 2.1 EX38 - ...
(CWL DWG ...

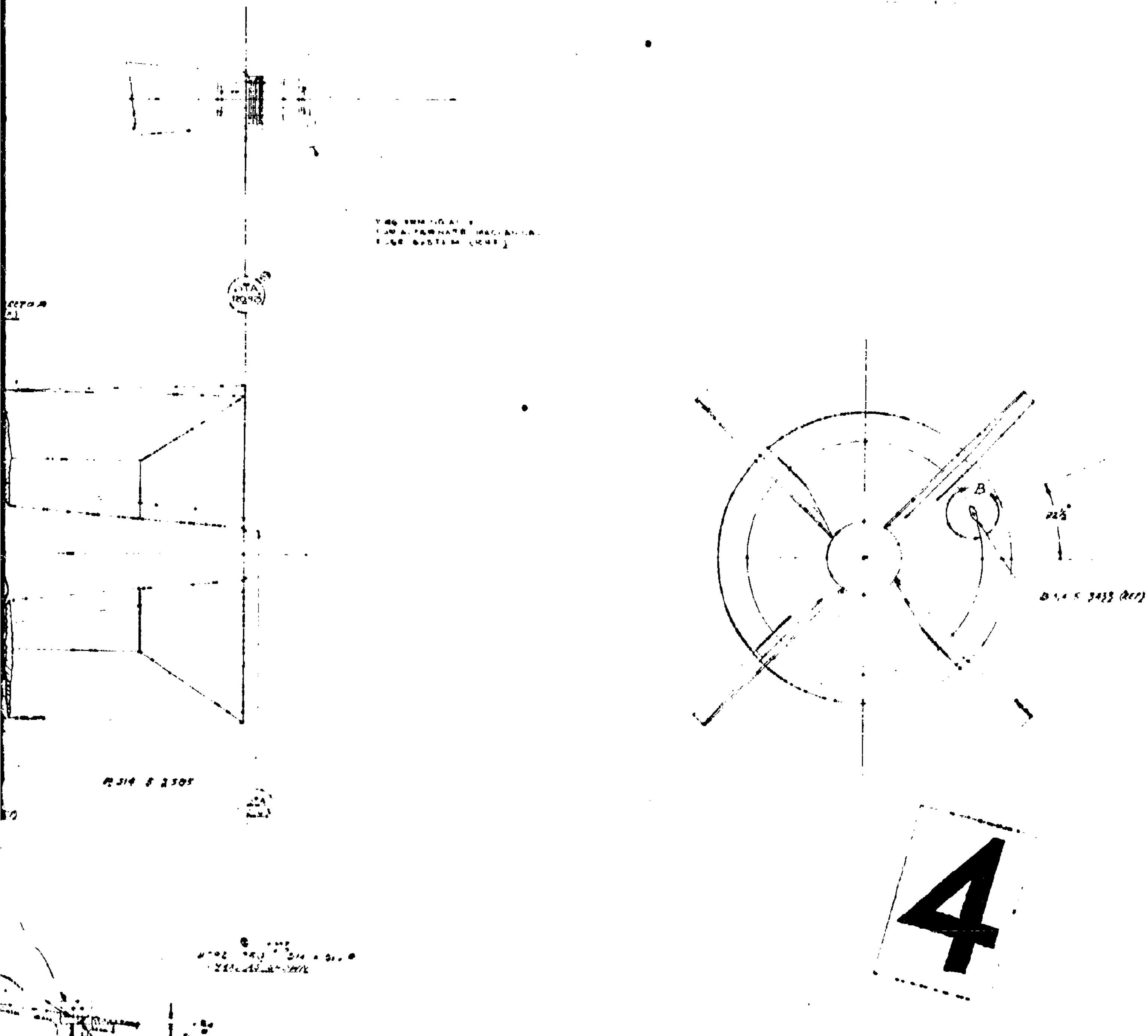


FIGURE 2.1 - EX 38 - 500 LB. CHEMICAL BOMB
(CWL DWG. B314 S [illegible]10)

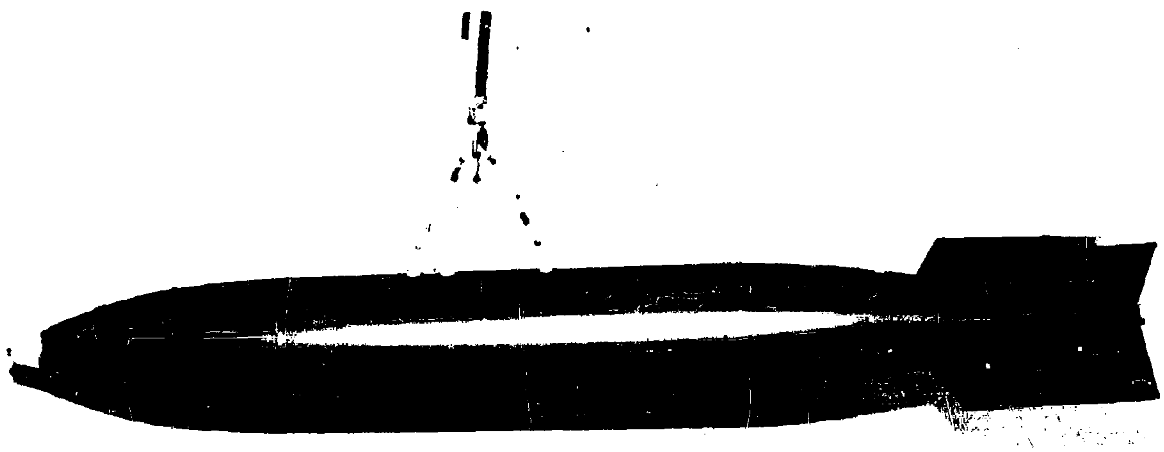


Figure 2.2 EX 38 Chemical Bomb

Figure 2.3 Tank Welding Setup, Rear End Removed

Figure 2.4 Completed Tank

Figure 2.5 Ballast and Nose Cone

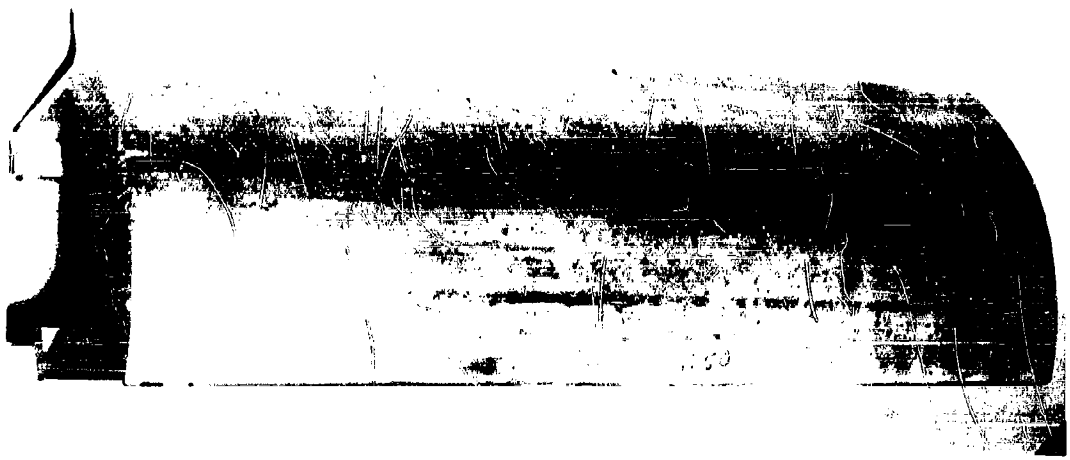


Figure 2.6 Strongback Extrusion

Figure 2. 7 Tank End and Center Hydrospinnings

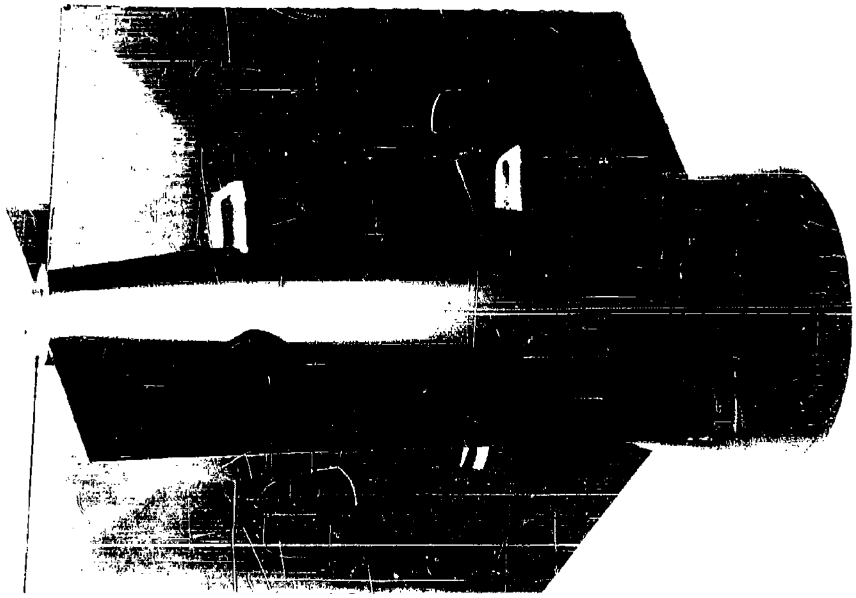


Figure 2.9 Tail Cone Assembly

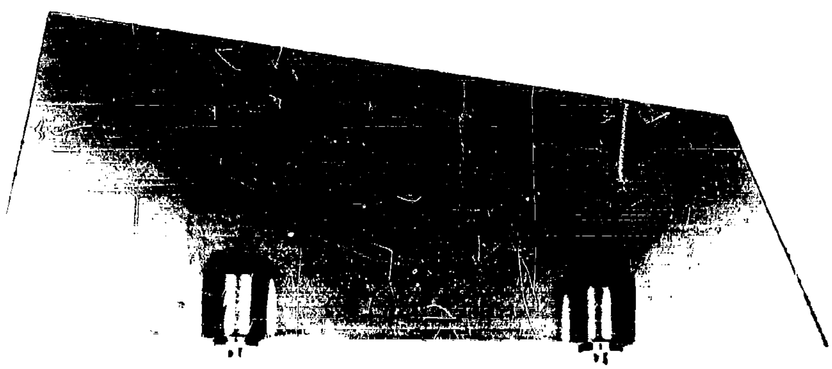


Figure 2.8 Tail Fin

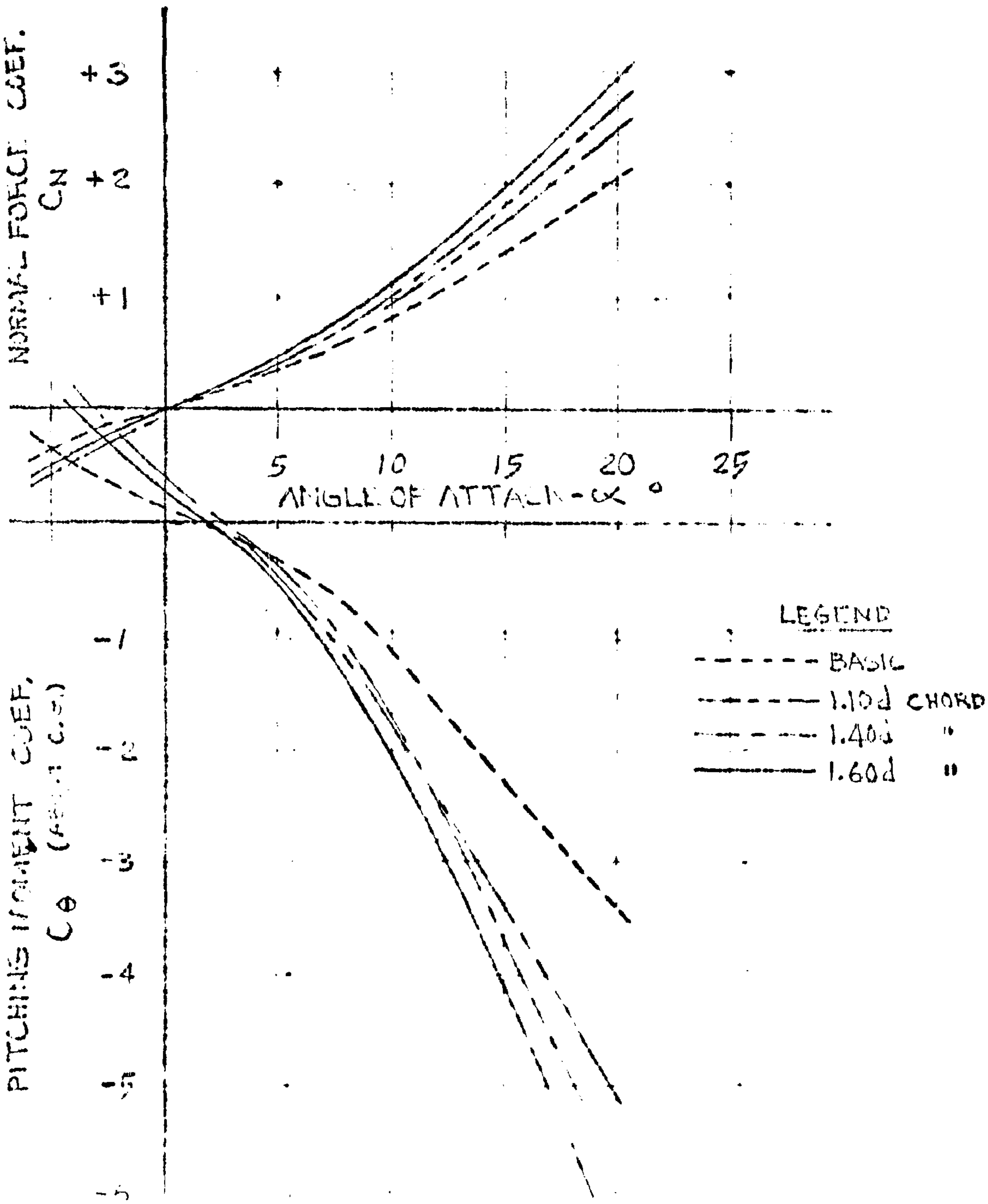


FIGURE 2.10a - Normal Force and Moment Coefficients vs. angle of attack - 0° Roll angle

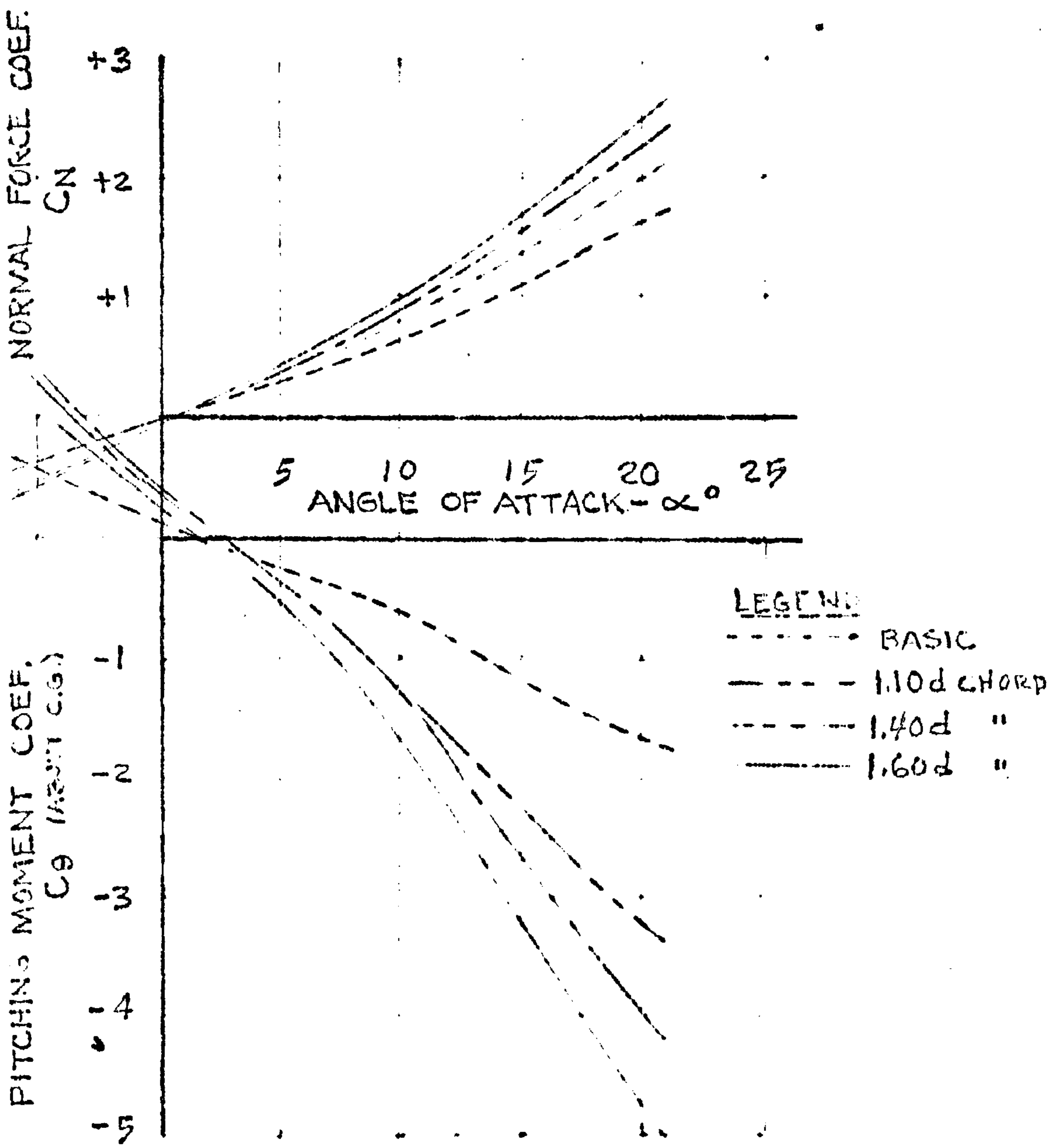


Figure 2.10b - Normal Force and Moment Coefficients vs. angle of attack - 45° Roll angle

3.0 PHASE II & III FABRICATION EXPERIENCE

3.1 General

Phase II consisted of producing detail manufacturing drawings and, after approval, fabricating two prototype items for structural testing by CWL. These prototypes were built and successfully tested without need of any redesign or modification. However, some of the fabricating experience here and in Phase III is worthy of note.

Of particular interest are the experiences with the hydrospinning process, the welding and leak testing, and the plastic tail fins.

3.2 Hydrospinnings

The basic hydrospinnings are shown in Figure 2.7.

The fore and aft ends and the center portion of the tank are made from two of the dome-like spinnings and one cylindrical spinning.

The dimensional control of these spinnings was disappointing. Originally it had been expected to achieve tolerances of ± .004 in. on the 14.00 inch O.D. and ± .003 on the .102 in. wall thickness. These tolerances were never met and the drawing requirements were changed to more realistic values of ± .010 on the diameter and ± .005 on the wall thickness. Even with these expanded tolerances some parts had to be accepted with excessive ovality and wall thickness. In these instances the parts were accepted because the ovality

is corrected in subsequent installation of the bulkheads and more important because the structural integrity was not impaired. However, the revised drawing tolerances are quite realistic and should be readily attainable in large quantity production where spinning techniques may be perfected.

Several of the out of tolerance cylindrical spinnings were heat-treated after rather than before the final spinning operation. It is suspected that this heat treatment may have caused some change in diameter. However, such distortion could be avoided in the future by having parts heat treated prior to the final spinning operation.

3.3 Welding and Leak Testing

The girth welds of the cylindrical portion to the end domes on the tank proved troublesome on some bombs. The trouble arose from excessive diametral mismatch of the mating parts. Although the mismatch was not enough to cause any weakening discontinuity or offset in the skin, it caused a dip in the bomb contour exceeding the drawing specifications. The problem was further aggravated by the backup rings (Frames at Stations 30.9 and 76.9; part D314-5-3413) being made to the low side of the drawing diameter tolerance.

In future production the matching ends of the dome and cylinder spinnings should match within the sum of the drawing tolerances, i.e. ± .020 in. on the diameter and the frames serving as a backup rings for this girth weld must

fit snugly. An additional sizing operation of these matching parts should be considered.

The assembled tank portion of the bomb was carefully checked to avoid leaks. The final procedure evolved consisted of a 100% X-ray check of all the welds subject to leaks. The fillet weld of the bayonet fitting and the nose cone tack welds, and the weld of the conduit tube to bulkhead were not X-rayed since they were not considered prone to leakage, since they did not run across the basic sealed volume. After the X-ray check, leak tests were conducted using a helium leak detector on two of the subassemblies a nd on the final bomb body assembly. This last leak test was accomplished after a 60 psi proof test. The other tests used low (15 psi) pressure.

Some repairs were intitated as a result of examination of the X-rays. However, some leaks were still present after the repairs. These leaks could not be detected on the X-rays at all, even after carefully locating their position on the X-ray picture. The obvious conclusion to be drawn from this experience is that the helium leak tests provide a far more sensitive quality control than do the X-rays. Thus the helium leak testing should be continued 100% of the time as outlined in Table 3.1. Whereas the X-ray checking could be reduced to less than 100% of the time. Table 3.2 is a record of the leaks discovered in this inspection program.

3.4 Plastic Tail Fins

In the design study many construction methods and material were considered for the tail fins including built up sheet metal, solid metal, honeycomb and reinforced plastics. The reinforced molded plastic material promised to be the most satisfactory material from a production cost point of view. Therefore, a fin was designed utilizing an Atlas Powder Company chopped fiber glass reinforced polyester modling compound; "Thermoflow 100". This material had the highly desirable characteristics of low molding pressure and temperature and moderately high strength.

During Phase II attempts were made to fabricate fins of this material, the metal mold was made and samples were molded. However, because of its relatively high mold shrinkage this polyester compound proved unsuccessful. The thin edges of the fin were excessively warped.

To complete Phase II without delay it was decided to fabricate the fin by hand lay-up in the mold using epoxy resin and many layers of trimmed glass mat reinforcing. Epoxy resin is known to have low mold shrinkage and with sufficient glass content very high strength is insured. The mold was closed on the finished lay-up to produce a smooth flat part. The resulting fins were highly successful although more expensive than the originally proposed fin. One sample fin was cut up for evaluation of its physical properties. These re-

sults are presented in Table 3.3. These results show consistently high glass content and strength throughout the entire part.

During Phase III the search for a low cost molded plastic fin was continued. Two fins were molded of a chopped glass reinforced phenolic compound (Durez 16771). These fins showed promise of meeting the requirements of low cost, good surface finish and flatness. However, they failed in static tests at 81% and 90% of the ultimate load. Figure 3.1 shows one of these fins under load and the resultant failure.

For any subsequent large scale production further consideration should be given to a beefed up fin design using the low cost phenolic compound. The following costs and estimates illustrate the savings that could be achieved with the phenolic molding material.

Fin Type	Cost per part when ordered in quantities of		
	48	2000	4000
Epoxy-lay up	$40.	-	25.
Phenolic Compound	$29.21	8.75	-

The $40 figure is the actual cost of the EX 38 fin. The $25 figure is the estimate used in computing the 1000 bomb cost given in Paragraph 5.2. The costs for the phenolic fins are taken from the Phase I work (See Edo Report 5150 Vol I pg.68 Vendor A). This quote is typical of what can be expected of a phenolic-glass fin.

TABLE 3.1

HELIUM LEAK TEST PROCEDURE

Assembly	Test*
1. Strongback, Bulkheads and arming wire conduit.	Pressurize conduit and check welds to strongback and to bulkhead.
2. Tank Assembly prior to nose attach. and aging.	Pressurize tank to 15 psig check all welds.
3. Final bomb body assembly R314-5-3377	Pressurize tank to 60 psig for 10 minutes then check for leaks at the 60 psig.

*No leak greater than 1×10^{-6} cc per second shall be acceptable. In all tests the pressurizing gas mixture shall contain that partial pressure of helium required for good detector sensitivity.

TABLE 3.2

RECORD OF HELIUM LEAK TESTS

NOTE: The Consolidated Electrodynamics Corp., leak detector #24-101A was used in all of the following tests:

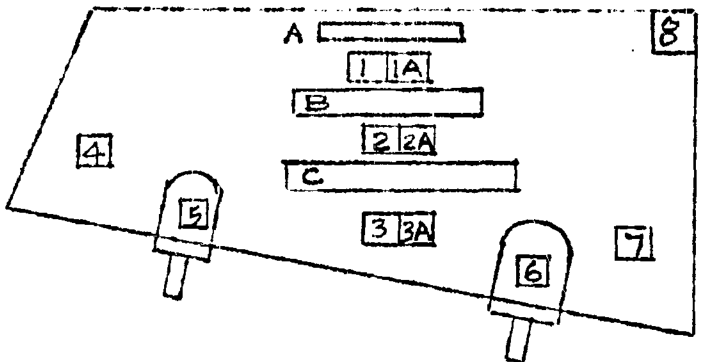
Test	Leaks Detected: Serial No.	Leaks Detected: Location of Leak	Repair & Retest
1* Strongback (Conduit Assy.)	None	No Leaks	None
2 Tank Assy.	1 & 2	Conduit Boss-Rear End	Repaired- No Leaks
	10	Conduit tube top outlet	Repaired- No Leaks
	11	2 Places strongback to skin	Repaired- No Leaks
3 Final Assy.	4	2 Places forward girth weld	Repaired- No Leaks

*This test was begun on serial No. 7. Nos. 1 thru 6 did not receive this test.

TABLE 3.3

PHYSICAL PROPERTIES OF GLASS REINFORCED EPOXY FIN DRAWING

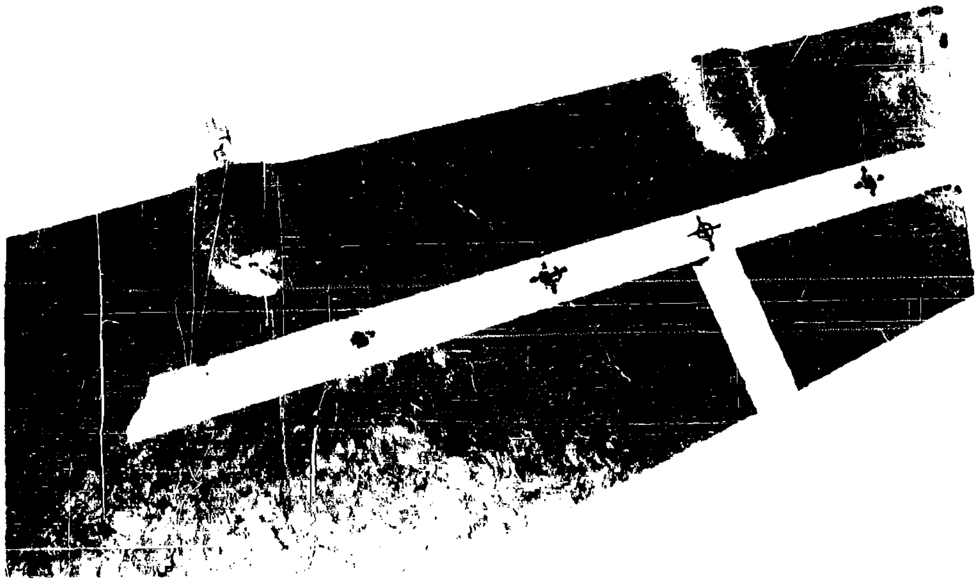
D314-5-3404



F_{BU} = Ultimate Bending Strength

E_B = Bending modulus of elasticity

Specimen No.	Resin Content	F_{BU} 1000 psi	E_B 10^6 psi	Sp. Gravity	Barcol Hardness
1	61.9%				42
2	52.7				35
3	49.0				45
4	53.2				43
5	62.4				46
6	55.2				33
7	48.5				38
8	52.5				46
1A				1.50	
1B				1.52	
1C				1.56	
A		50.0	2.01		
B		43.2	1.72		
C		42.7	1.91		



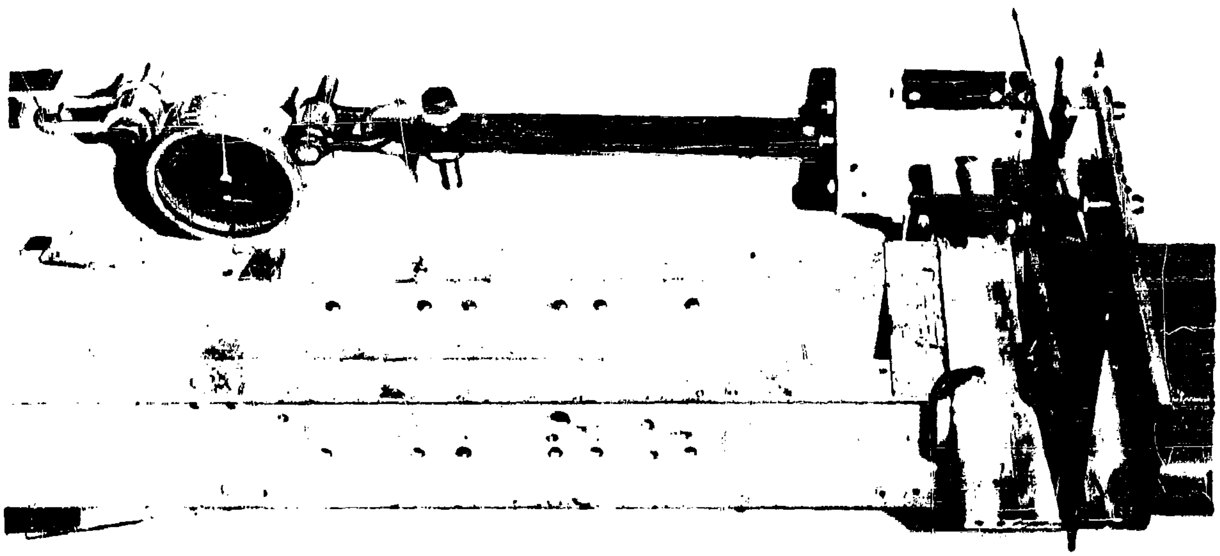


Figure 3.1 Phenolic Fin Test and Failure

4.0 SUMMARY OF CWL PROTOTYPE EVALUATION

4.1 General

The Chemical Warfare Laboratories subjected the two Phase II prototype bombs to a series of tests; filling and handling tests were included as well as structural tests.

Tests conducted were:

1. Filling and weighing tests
2. Catapult tests
3. Ejection tests
4. Drop test
5. Static tail load tests

The weight and volume data in Table 2.1 is a result of CWL's filling and weighing tests. In these tests the c.g. was found to shift only 1.3 inches while tipping the bomb from nose down to nose up. Thus the slosh baffle performed satisfactorily. Without this baffle calculations show a c.g. travel of 4.5 inches as the liquid rushes from nose to tail.

4.2 Catapult and Ejector Tests

Catapult and ejector tests were conducted on both prototype bombs to simulate the inertial flight loads and store ejection loads. These tests were conducted on the catapult and arrested landing facility and on the bomb ejector facility of the U.S. Naval Weapons Laboratory, Dahlgren, Va.

The catapult tests simulated the forward, aft, and sideways accelerations and load factors required by MIL-A-8591.

Each bomb was filled with water and assembled with tail cone, dummy burster and fuzing system. Both fuzing systems were used. Figure 4.1 shows the first bomb with mechanical fuzing mounted on the catapult car. Ten launchings were made altogether; the results are listed in Table 4.1. The bombs survived these tests with no damage except for a slight dent (on one bomb only) under the loaded sway brace pads after the ultimate side load test. This denting occurred only because the sway brace pads contacted the bomb 40° down from the center instead of within the 30° reinforced area either side of the top center as required by MIL-A-8591.

After the catapult tests, the bombs were mounted in a nose down attitude on the bomb ejector tower (Figure 4.2) and subjected to a horizontal ejection from an Aero 7A ejector. The maximum standard Navy powder charges were used in the ejector; one MK 1, Mod. 3 plus one Mk 2, Mod. 1. The bomb was caught in a saw dust pile to prevent extraneous damage. No significant damage was noted on either bomb.

From the results of these tests it was concluded that the EX-38 Chemical bomb is structurally sound and will withstand the aerodynamic and inertial flight loads encountered on carrier based aircraft.

4.3 Drop Test

One of the two prototype bombs was subjected to the

ten foot drop test specified by the design requirements. The test setup and bomb damage is shown in Figures 4.3 and 4.4. The bomb was filled with water, with an 8 to 10% void, and the dummy burster.

The nose cone and ballast assembly came off cleanly at the skip welds to the tank, and the bottom of the tank was flattened along its length. In Figure 4.4 the bomb has rolled over after impact thus the flattened bottom is the upside. This flattened area is somewhat obscured in the photograph, but it can be seen on close examination of the photograph.

After the drop test a helium leak test showed no leaks had been opened up as a result of the drop damage. To facilitate the leak test all traces of water were removed by drying the emptied tank in a 160°F storage chamber.

After it was clear that no leak resulted from the drop damage, the tank was cut open and the internal damage noted. All bulkheads were crumpled on the bottom, the rear strongback bulkhead was torn at the gusset weld, this gusset in turn was ripped at the edge margin of the lowest bolt row, and the forward bulkhead weld to the skin was ripped loose for a distance of 8 inches. This damage was all internal and hence did not affect the leak tightness of the tank.

The clean separation of the nose and ballast from

the tank upon impact should be noted. This was the intention of the design. With only skip welding to the tank and no attachment or interference with the burster tube, the nose was meant to break off without deforming the tank or the joint of burster tube to tank. With this design there is little likelihood of a tear, crack or rupture of the tank, if the bomb strikes nose first. The test proved this design philosophy to be correct.

The drop test was conducted at CWL during October 1960.

4.4 Tail Tests

The tail fins, cone and bayonet attachment were designed by free flight load conditions with the bomb pitched up at an angle of 20 degrees. Since this load condition could not be verified on the catapult or ejector tests, Edo recommended that static load tests be conducted on the prototype bombs. The CWL conducted these as indicated in the test setup of Figure 4.5. Limit and ultimate loads (safety factor of 1.5) were applied at the assumed centers of pressure by hydraulic jacks. The loadings are listed in Figure 4.6. After application of the limit and ultimate loads, no permanent deformity of the fins, tail cone or bayonet attachment was noted.

TABLE 4.1

CATAPULT AND EJECTOR TESTS RESULTS

Date	Launching No.	Ejection No.	Type of Suspension	Bomb No.	Attitude	Acceleration (g's)	Cartridge Type	Remarks
9/29/60	1		Aero 7A	1	Nose fwd.	9.2	--	No Damage
9/29/60	2		Aero 7A	1	Nose fwd.	11.6	--	No Damage
9/29/60	3		Aero 7A	1	Tail fwd.	10.4	--	No Damage
9/29/60	4		Aero 7A	1	Nose fwd.	12.8	--	No Damage
9/29/60	5		Aero 7A	1	Tail fwd.	14.8	--	No Damage
9/29/60	6		Aero 7A	1	Side	9.2	--	No Damage
9/29/60	7		Aero 7A	1	Side	12.4	--	*
9/30/60	8		Aero 7A	2	Nose fwd.	13.6	--	No Damage
9/30/60	9		Aero 7A	2	Tail fwd.	14.4	--	No Damage
9/30/60	10		Aero 7A	2	Side	12.6	--	No Damage
9/29/60		1	Aero 7A	1	Nose Down		1 Mk 1, Mod 3 1 Mk 2, Mod 1	No Damage
9/30/60		2	Aero 7A	2	Nose Down		1 Mk 1, Mod 3 1 Mk 2, Mod 1	**

*Slight dent under loaded sway brace pads.

**Slight dent under ejector pad.

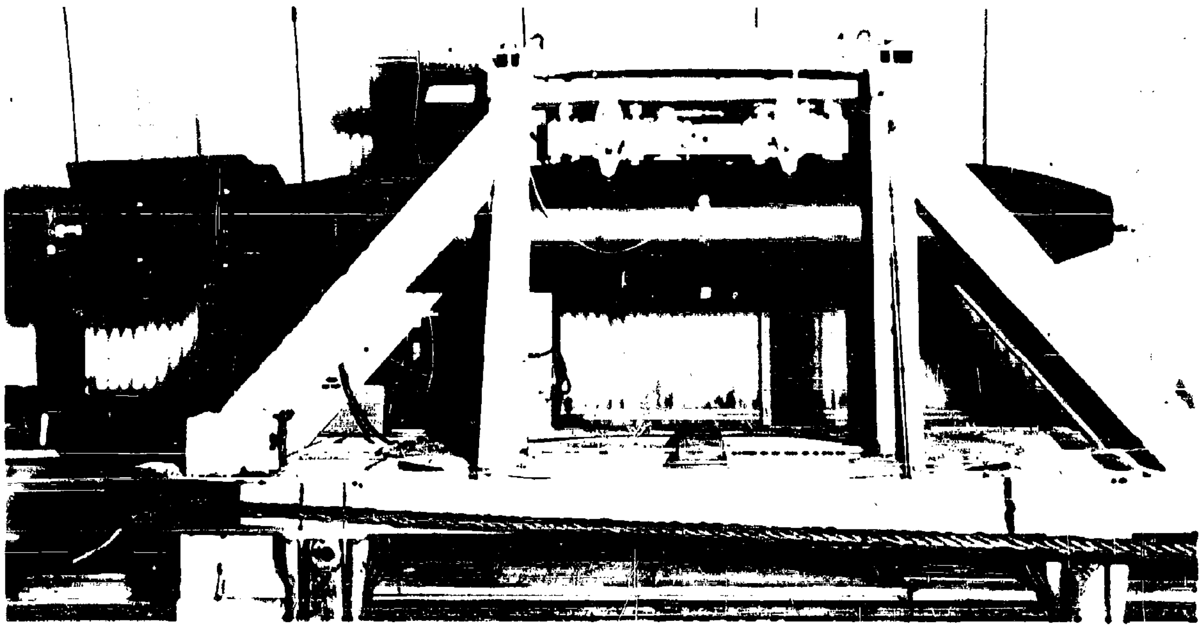


Figure 4. 1 View Showing EX-38 Chemical Bomb Suspended from Catapult Car in a Nose Forward Attitude

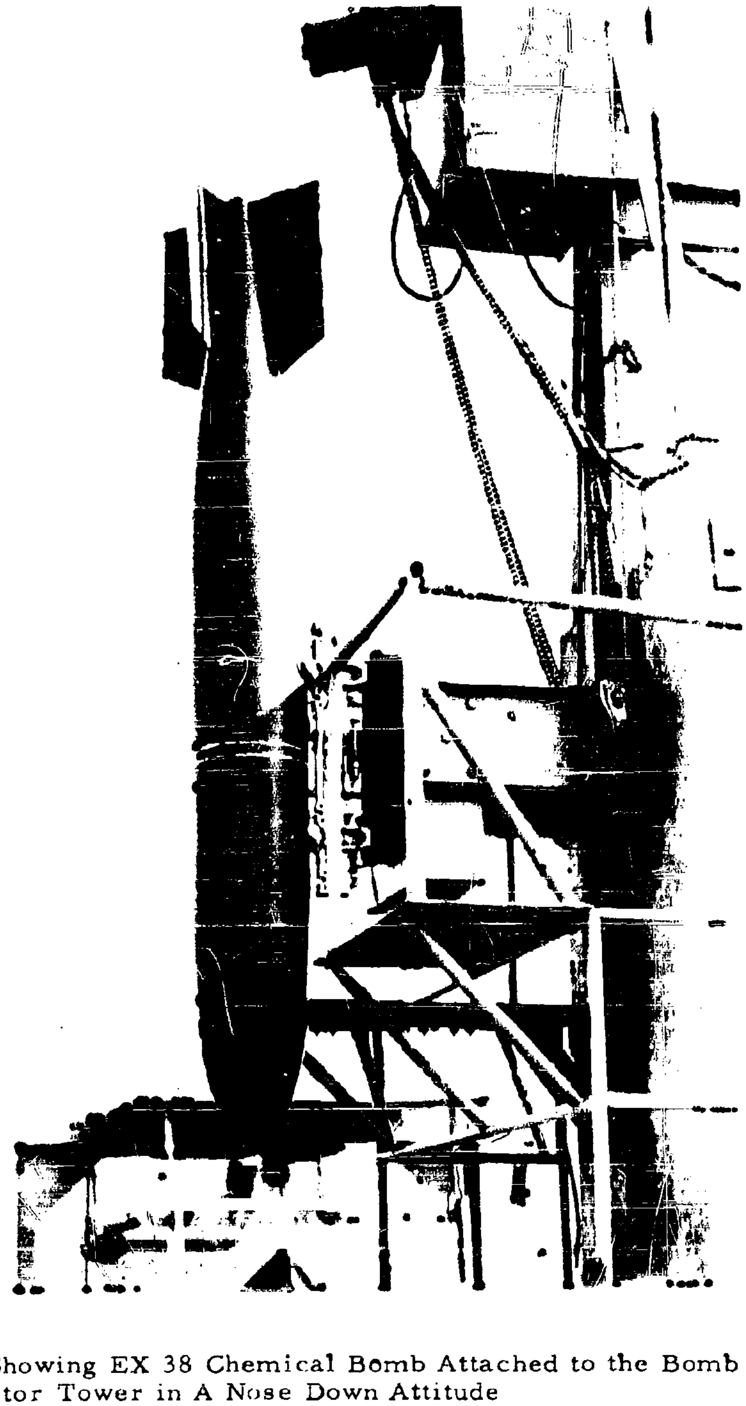


Figure 4.2 View Showing EX 38 Chemical Bomb Attached to the Bomb Ejector Tower in A Nose Down Attitude

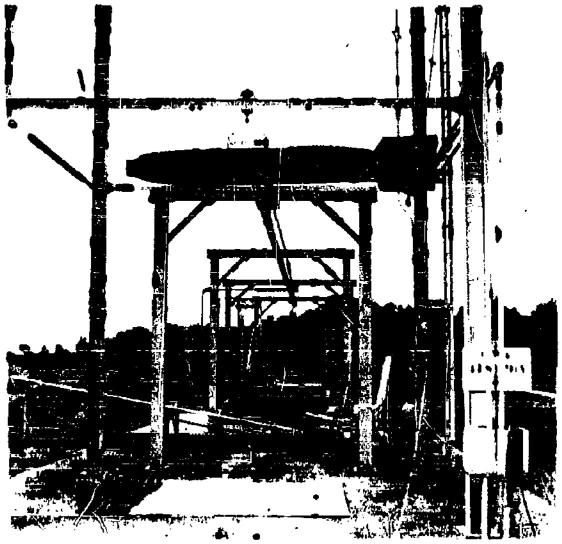


Figure 4.3 Bomb Drop Test

Figure 4.4 Drop Test Damage

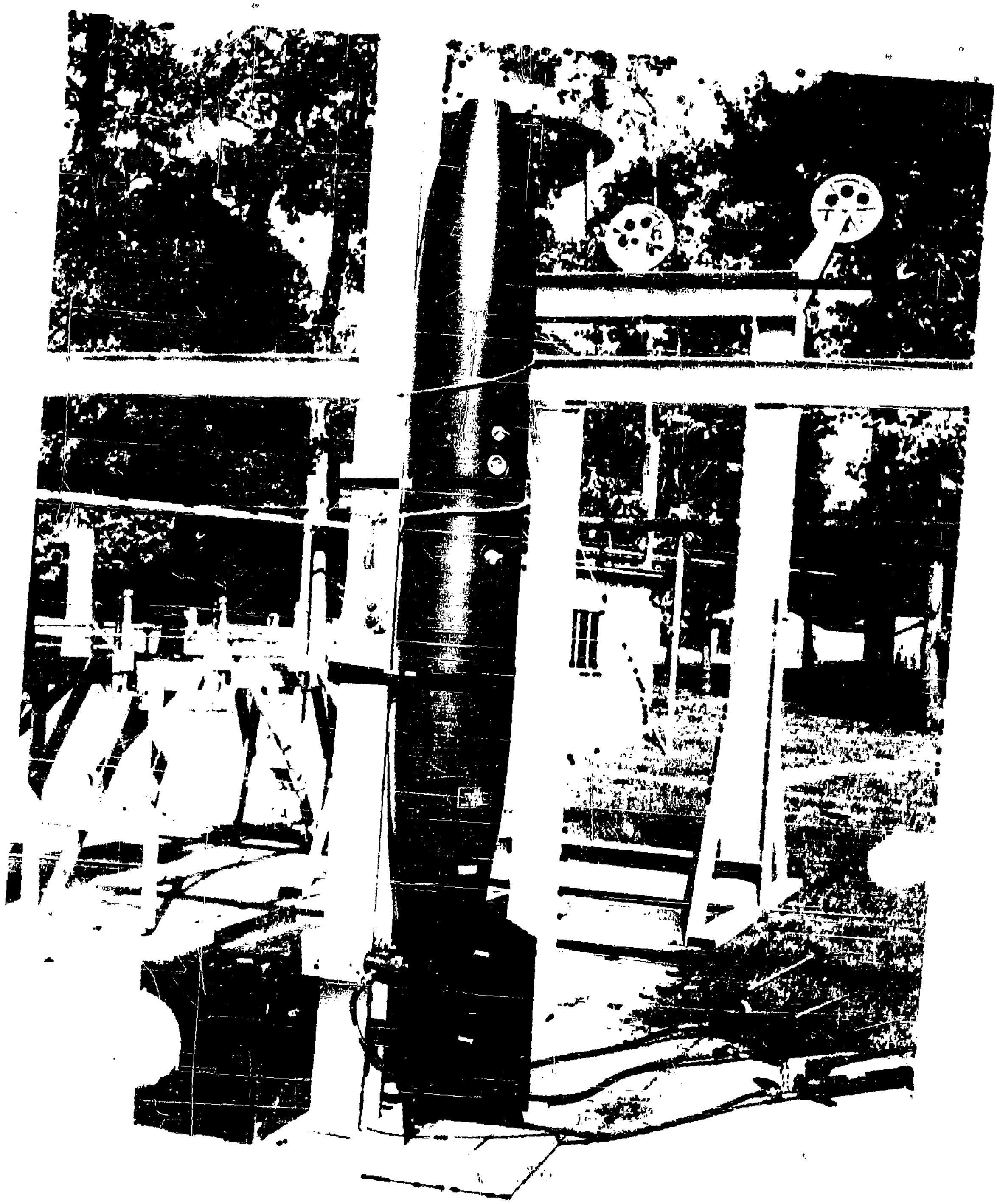


Figure 4.5 Test of Tail Fin and Tail Cone Assembly

5.0 COST ANALYSIS

5.1 Breakdown of Contract Costs

The actual contract costs breakdown is as follows:

1.	Total engineering - Design and Development	$52,000
2.	Total tooling	28,200
3.	Total fabrication costs - 12 bombs --	52,200
4.	Grand Total Costs	$ 132,400

These costs do not include the fixed fee nor are they meant to be an official cost accounting. They are presented only as a simple breakdown of costs for reference and aid in predicting future production rates.

Of the total of twelve bombs, two were produced under Phase II and ten under Phase III of the contract.

To give a rough idea of the detail costs that went into making up the overall costs of the first twelve units, costs of some of the larger components are listed here:

Part No.	Title	Unit Cost	No. Req'd.
D314-5-3408	Tank End Spinning	$90./each	2
D314-5-3411	Center Tank Spinning	155.	1
E314-5-3376	Machining Strongback	150.	1
(C314-5-3387 TYPICAL)	Bayonet	90./each	2
Total Welding	Labor	320.	-

5.2 Production Costs for 1000 Bombs

The estimated unit cost for 1000 bombs is $1300 per bomb. This estimate is given to aid in the prediction of large scale production costs.

The $1300 estimate does not include any additional tooling costs. However, it does assume that additional production fixtures will be supplied to reduce unit labor costs. The actual costs of these tools will vary if delivery schedules are such as to require duplication of tools. Furthermore, the cost estimate is based on the current design as pictured in Figure 2.1 with no major change in manufacturing processes. Design changes to facilitate other manufacturing processes (see paragraph 5.3) may have significant effects on production costs. The possibility of such changes should not be overlooked; however, they have not been considered here.

Furthermore, this estimate assumes that all welding is still done by hand. It has been estimated that for quantities greater than 1200 units, automatic welding will become economically feasible and the unit cost will be reduced.

5.3 Cost of additional tooling for single girth weld design. (Edo Drawing X-27955)

During the current contract an estimate was made of the cost of switching to a single girth weld design.

This estimate is included here for completeness. The additional tooling costs would be $25,200. All of this cost is primarily hydrospinning tools. The existing spinning tools cannot be converted for use on this design.

In addition to the extra tooling costs, some added engineering costs would be incurred since this design would entail a different strongback supporting structure.

APPENDIX A - PARTS LISTS

R314-5-3370 EX38 Chemical Bomb Assembly

Part No.	Name	Quantity Required
R314-5-3377	Forward Body Assembly	1
R314-5-3385	Aft Cone Assembly	1
B314-5-3372	Fuse Retainer - Aft.	1
B314-5-3419	Connector Lock Assembly	1
B314-5-3425	Connector Lock	1
B314-5-3427	Plug Nylon	1
B314-5-3430	Gasket - Connector	1
B314-5-3433	Bayonet Locking Pin	1
C314-5-3384	Fuse Well Assembly	2
B314-5-3434	Stencil	1
C314-5-3371	Lines Drawing-Chemical Bomb	(Ref.)
AN 6390-12	"O" Ring	1
MS 9015-12	Plug (Alternate MS123130)	1

R314-5-3377 Forward Body Assembly

Part No.	Name	Quantity Required
D314-5-3405	Nose Ballast Assembly	1
D314-5-3406	Nose Spinning	1
D314-5-3407	Nose Ballast Casting	1
AN509-10-7	Screw	10
---	Tank Assembly (See separate Parts List)	1

Tank Assembly (Ref. R314-5-3377)

Part No.	Name	Quantity Required
D314-5-3378	Burster Tube	1
D314-5-3373	Tank End - Forward	1
D314-5-3408	Tank Spinning	1
C314-5-3409	Tank Spin. Preform	1
R314-5-3410	Center Tank Assembly - Welded	1
E314-5-3422	Tank End Assembly - Aft	1
D314-5-3408	Tank Spinning	1
C314-5-3409	Tank Spin. Preform	1
C314-5-3424	Bayonet Ring	1
B314-5-3431	Aft Tank Filler Fitt'g.	1
B314-5-3418	Conduit Terminal	1

R314-5-3410 Center Tank Assembly - Welded

Part No.		Name	Quantity Required
D314-5-3411	Center	Tank Spinning	1
C314-5-3412		Cent. Tank Spin. Preform	1
D314-5-3413	Center	Tank Frame	2
-	Frame	& Strong Back Assembly	1
D314-5-3414		Frame Sta. 39.637	1
D314-5-3415		Frame Sta. 63.013	1
E314-5-3376		Machining Strong Back	1
B314-5-3375		Extrusion Strong Back	
B314-5-3416		Conduit Tube	1
B314-5-3417		Conduit Seal	1
B314-5-3420		Center Tank Baffle	1
B314-5-3421		Gusset Plate	4
B314-5-3423		Shim	4
AN500-10A		Boltz	24
AN960PD516		Washer	24
AN365D524		Nut	24

R314-5-3385 Aft Cone Assembly

Part No.	Name	Quantity Required
C314-5-3386	Aft Cone Shell	1
C314-5-3387	Aft Cone Ring Bayonet	1
B314-5-3388	Aft Cone Closure Fitting	1
C314-5-3389	Aft Cone Fwd. Fin Ring	1
C314-5-3403	Aft Cone Aft Fin Ring	1
D314-5-3404	Fin Assembly	4
B314-5-3432	Insert-Fin	8
B314-5-3428	Splice-Cone Shell	1
AN426AD5-8	Rivet - CSK	46
AN365-624	Nut	8
AN960PD616	Washer	8
AN426AD3-7	Rivet - CSK	2
AN426AD4-5	Rivet - CSK	80
AN426AD4-6	Rivet - CSK	23
AN26AD4-16	Rivet - CSK	76
22NA5-02	Nut-Plate	1
25-A	Caplug	1

D314-5-3379 Burster Charge Assembly

Part No.	Name	Quantity Required
C314-5-3380	Burster Charge Tube	2
B314-5-3381	Burster Conduit Tube	2
B314-5-3382	Burster Cond. Tube Nut	2
B314-5-3383	Burster Cap	2
	Explosive Charge Comp. B	
B314-5-3429	Burster Cap Inner	2

AD ________ Accession No. ________ UNCLASSIFIED

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

1. Bomb, Chemical
2. Chemical Warfare

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ________ Accession No. ________ UNCLASSIFIED

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

1. Bomb, Chemical
2. Chemical Warfare

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ________ Accession No. ________ UNCLASSIFIED

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

1. Bomb, Chemical
2. Chemical Warfare

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ________ Accession No. ________ UNCLASSIFIED

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

1. Bomb, Chemical
2. Chemical Warfare

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ______ Accession No. ______

UNCLASSIFIED

1. Bomb, Chemical
2. Chemical Warfare

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ______ Accession No. ______

UNCLASSIFIED

1. Bomb, Chemical
2. Chemical Warfare

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ______ Accession No. ______

UNCLASSIFIED

1. Bomb, Chemical
2. Chemical Warfare

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.

AD ______ Accession No. ______

UNCLASSIFIED

1. Bomb, Chemical
2. Chemical Warfare

Edo Corporation, College Point, N.Y.
FINAL REPORT - EX38 - 500 LB
CHEMICAL BOMB DEVELOPMENT
Taranto, F. F., Klurfeld, S.

Report No. 5412, 31 AUG. 61, 53 pp, 18 figs, 5 tables
Contract DA 18-108-405-CML-438
CP9-405-14115

The purpose of this contract was to design, develop and fabricate twelve production prototypes of a highly efficient 500 lbs., massive chemical warfare, fragmentation bomb. Efficient payload and aerodynamic characteristics compatible with current Navy shipboard aircraft were the most important objectives. All work done under this contract, including the results of the CWL test evaluation of the first two prototype bombs delivered, and the experience gained during fabrication of the bombs is summarized.